CHAPTER

2

Drawing With Pen, Ruler, and Instruments

This chapter provides general instructions for making drawings with pen, ruler, and instruments. However, it is beyond the scope of this book to go into great detail on basic drawing skills, which are already covered in many other books. The advantage of making drawings with pens and rulers is that the tools are relatively inexpensive. The drawback is that, because ink marks cannot be easily corrected, there is little room for making mistakes. If you can be very careful in laying down ink lines, drawing manually is still a viable technique.

Additional Reading

For basic drawing skills, we suggest:

- *Basic Drawing Techniques*, by Greg Albert and Rachel Wolf (North Light Books)
- *Keys to Drawing*, by Bert Dodson (North Light Books)
- *The New Drawing on the Right Side of the Brain*, by Betty Edwards (HarperCollins), and
- *Learn Cartooning and Drawing the Easy Way*, by Bruce Blitz (Art Products, Inc.).

Necessary Tools and Supplies

All the traditional drawing tools and supplies you will need can be found at an art supply store. If there is no such store in your area, you can request catalogs or shop online at art supply outlets, such as Blick art supplies (www.dickblick.com) and Flax Art & Design (www.flaxart.com).

Generally, a drawing of a physical object requires the greatest number of tools because of its complex lines, whereas a drawing of graphical symbols, such as flowcharts and electrical schematics, requires fewer tools because of the simple, regular shapes. Usually, you will not need a complete set of drawing tools; what you need depends on what you want to draw and how you want to draw it. You can determine the tools and supplies you need after you have read this chapter. You also may try drawing in pencil after reading this chapter to see if you can produce satisfactory drawings before you invest in new tools and supplies.

Essential Tools and Supplies

The following tools and supplies are essential for traditional, manual drawing techniques:

- **Pencils, either wood or mechanical, for making light, erasable sketches.** A soft lead pencil, such as 2B, is usable as long you draw lightly with it. A medium lead pencil, such as HB or F, is probably more suitable. A hard lead pencil, such as H or above, is generally not suitable, because too much pressure is needed to make a visible line, and the pressure will tend to score grooves in the paper.
- **A soft or kneaded eraser for erasing pencil marks without harming paper.** A good brand of soft eraser is Staedtler, by Mars Plastic. Soft erasers are easier to handle, but they leave debris on the drawing that must be brushed away. Kneaded erasers, which are usually available only at art supply stores, are pliable and do not leave debris. They must be kneaded, like dough, to push in the dirtied parts and bring the clean inner parts to the surface. You may also wish to get an electric eraser, which is handy for erasing long ink lines.
- **Technical pens for drawing ink lines.** Technical pens are ink pens made specifically for precision ink drawings. They come in different sizes; you should have at least the 0.13 mm and 0.25 mm sizes. Well-known brands include Koh-I-Noor Rapidograph and Rotring Rapidograph, which cost about

$20 each. Alternatively, good quality, extra fine to medium point, felt-tip or plastic-tip pens, which are only about $2 to $3 each, may be used. A good brand is Tech-Liner Pens by Alvin. Do not use ballpoint pens, rollerball pens, or fountain pens, because they do not make lines that are sharp and black enough to meet Patent and Trademark Office (PTO) standards.

- **Nonclogging black ink for the pens, unless you use the prefilled models.** Some good brands include Higgins Black Magic and Rapidograph Ultradraw.
- **White correction fluid with a pen-type applicator.** A good brand is Pentel Quick Dry correction fluid. We recommend the pen type, rather than the brush applicator because the fluid in a pen-type applicator is less likely to thicken or dry out.
- **A drafting board with a built-in parallel ruler and protractor.** A drawing board can be plain or can have a built-in ruler that slides in a parallel fashion up and down or left and right on the board. This enables you to accurately draw parallel lines, vertical lines, horizontal lines, or lines at any other angle. A board with a built-in ruler is practically an essential tool. Rotring sells an inexpensive model (about $60) under the trademark Koh-I-Noor Portable Drafting System. Alternatively, a T-square (a T-shaped device for sliding up and down or left and right along the edges of a plain, rectangular drafting board) may be used. You may also dispense with the drafting board by using the corner of a table with a smooth surface to guide the T-square. If you use a T-square, you will also need a set of triangles and a protractor for drawing lines of different angles. The overall cost of assembling these components may not be lower than the Koh-I-Noor Portable Drafting System, depending on the quality of the components, and they are definitely more difficult to use, because you have to keep the T-square and the triangle aligned properly while you control the pen.
- **Lettering guides (templates) for writing text.** To print neat text, ⅛" and ¼" letter guides are available for use with a drawing pen. Alternatively, transfer type (rub-on lettering) of a simple typeface or style in the same sizes may also be used. The guides cost about $5 each, and transfer type costs about $13 per sheet.
- **Masking tape.** To tape down drawing paper on the drafting board, use only tape that does not damage paper. Post-It® brand or regular masking tape will do.
- **Parchment tracing paper for tracing photographs or sketches.** Any brand will do.
- **Vellum or Mylar for finished drawings.** Vellum is a tough, matte (frosted), translucent paper that takes ink very well, and can be repeatedly erased without damage. Mylar is a very tough plastic film; use the kind that has a matte rather than glossy surface. A proper ink drawing paper must be used, because other papers will cause the ink to feather—that is, seep between the paper fibers—and spread out. Vellum costs about $18 for 100 sheets. Since it is difficult to erase lines on bristol board, we do not recommend using it for finished patent drawings. Always keep the originals of your drawings and send high quality photocopies on bond paper to the PTO.
- **An electric eraser.** To erase ink lines, a rotary electric eraser with a lightly abrasive eraser works best. About $15 to $60.

Additional Tools Recommended for Drawing Physical Objects

In addition to the tools listed above, the following are useful for drawing physical objects:

- **An engineer's triangular scale (a six-sided ruler) for drawing to scale.** One side of the triangular scale is marked with full-size inches with ten divisions each, and other sides are marked with ½, ⅓, ¼, ⅕, and ⅙ scale inches. For example, on the ½ scale side, each inch mark is ½ the size of an actual inch. Scales are as low as $5 each.
- **Various circle templates (plastic sheets with holes) for drawing circles of different, fixed sizes.** These cost about $7 each.
- **Various ellipse templates for drawing ellipses of different, fixed sizes and shapes.** An ellipse is the shape a circle takes when seen at an angle. These cost about $7 each.
- **Triangles with beveled edges.** Triangles (30° and 45°) with beveled edges are necessary for preventing ink from seeping under them. They are as low as $4 each.
- **A compass capable of holding a technical pen for drawing circles and arcs of custom sizes.** Such a compass costs about $25.
- **An ellipsograph for drawing ellipses of custom sizes and shapes.** Although it will enable you to draw an ellipse with the exact shape desired, an ellipsograph is more difficult to use than an ellipse template, because it has to be carefully adjusted and positioned to get the desired results. It has reportedly been discontinued by the manufacturer, but some vendors may still have them in stock.
- **Various French curves (templates with many curved edges of fixed shapes) for drawing uneven curves.** French curves require a lot of practice to use, because it is often difficult to find an edge with the desired curvature (about $8 for a set).
- **A flexible (adjustable) curve for drawing custom-shaped curves.** A flexible curve or spline (about $6) may be used instead of a French curve, but you will have to adjust it every time you need a different shape.
- **A transparent grid overlay.** This is a transparent plastic sheet with a grid etched on it for plotting difficult shapes.
- **Preprinted grid paper.** Available in various sizes, including inch, metric, isometric, and perspective, this is used under a sheet of tracing paper to serve as a guide.

Additional Templates for Drawing Graphical Symbols

To draw graphical symbols, you may want to have one or more symbol templates. They are available for a variety of specialized symbols, such as electronics, architectural, and flowchart symbols.

Additional Tools for Tracing Photographs or Sketches

For tracing photographs or sketches, you may want these additional tools:

- **A light box.** A box with internal light and translucent white top (about $80).
- **Clear polyester film.**

The pantograph (a mechanical parallelogram device) is also available for tracing drawings. It may be adjusted to make a drawing at various scales to the original. However, it produces very inaccurate results, so it is not recommended. A photocopier may be used to make enlargements or reductions much faster and more accurately.

Additional Tools for Tracing Actual Objects

You may want these additional tools for tracing actual objects:

- **A camera lucida.** This clever device includes a lens mounted on an adjustable arm for projecting an image of an actual object onto a drawing surface at selectable magnification or reduction, so that the image size on the paper may be adjusted. Interestingly, this device was invented back in 1807. It is available at Flax Art & Design for several hundred dollars. It is relatively difficult to use. (See Illustration 2.5.)
- **A homemade, direct-view tracing device that includes a 12" × 24" sheet of ⅛" thick transparent acrylic or Plexiglas, and a device for supporting the transparent sheet above the object being traced.** The acrylic sheet is available at plastic supply stores, such as Tap Plastics (www.tapplastics.com). Avoid using glass, which may break and cause injuries. There is no commercially available supporting device suitable for this purpose, so you will have to create your own with your inventive ingenuity. Below, we provide some suggested solutions.
- **Clear polyester film.** This is for use with the homemade, direct-view tracing device (not the camera lucida, which projects an image onto paper).

Total Cost of Tools

The cost of a set of tools and supplies may range from as little as $100 to several hundred dollars, depending on your particular needs and how frugal you are. Note that some simple CAD (computer aided drafting) programs are free while more complex CAD programs cost several hundred dollars. If you already have a computer, you may want to read Chapter 3, which deals with computerized drafting, to see if you prefer to use the computer instead. If you do not have a computer, then drawing with pens and rulers is the most economical way to go.

Basic Drawing Rules and Techniques

Everyone planning to make a patent drawing with pens and rulers should review the rules and techniques described in this section.

A List of Rules and Techniques

To produce good drawings, you will need to apply the following basic rules and techniques:

- Always sketch a drawing lightly in pencil first, then apply ink lines over the final pencil marks.
- All ink lines should be drawn with the aid of guides, such as rulers, templates, and French curves. Use freehand drawing only when there is no alternative.
- Position the pen substantially vertically, and apply even pressure when moving it for a smooth and even line. Do not tilt the pen when you move it; otherwise the line width will be uneven.
- Avoid going over a line for a second pass; otherwise the line will become too thick or uneven due to the slightly changed position of the pen on the second pass.
- Position the pen so that the point of its tip does not touch the edge of rulers and other guides, or the ink will touch and spread under the guides.
- After drawing a line, pull or lift the guide straight up without crossing over the line to avoid smearing the ink.
- Wait patiently until ink lines dry completely before putting anything over them, erasing

pencil marks near them, or erasing misplaced ink lines; otherwise you will smear the ink. Generally, ink takes a few seconds to a minute to dry completely. Look closely at the ink lines; if they are shiny, they are still wet.

- Avoid erasing ink lines as much as possible, because erasing roughens the paper. Subsequent ink lines drawn over the roughened area will feather or bleed out. If you do have to erase ink lines, use an electric eraser *very lightly*, taking a long time and repeated passes to erase the ink lines.
- Use white correction fluid for covering unwanted ink marks. Make sure the ink is dry before applying the correction fluid. Dab the fluid on quickly and sufficiently so you don't have to go over the same area again, because that tends to roughen the fluid as it dries. This surface may not take ink well and may show up as blotches in photocopies. Do not rub the fluid on, because this may mix the ink with it.
- Lines that meet to form sharp corners must touch precisely without overlap, as shown in Illustration 2.1.
- Rounded corners should be created by drawing the curved segment first, then drawing the straight lines from the ends of the curved segment, as shown in Illustration 2.2.
- Erase pencil marks by holding down the paper with one hand, and stroking an eraser along the paper away from the hand holding the paper. Do not stroke the eraser back and forth, because—unless the paper is secured all around—the eraser will push the paper toward the hand holding it and wrinkle it.
- Make full use of the space on each sheet of paper to make a drawing as large as necessary to show all details clearly.

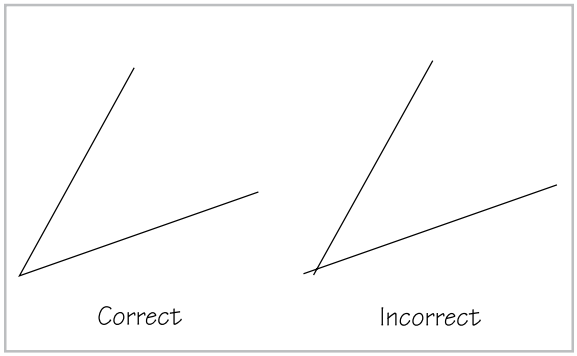


Illustration 2.1—Lines Forming Corners

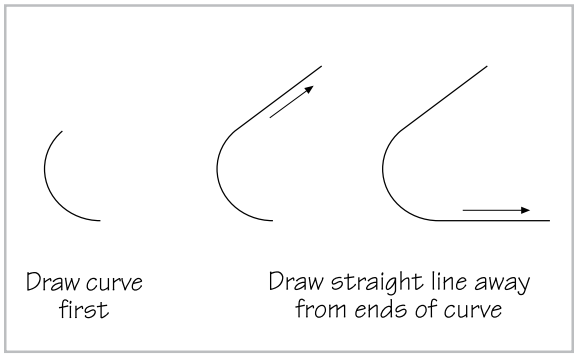


Illustration 2.2—Drawing Rounded Corners

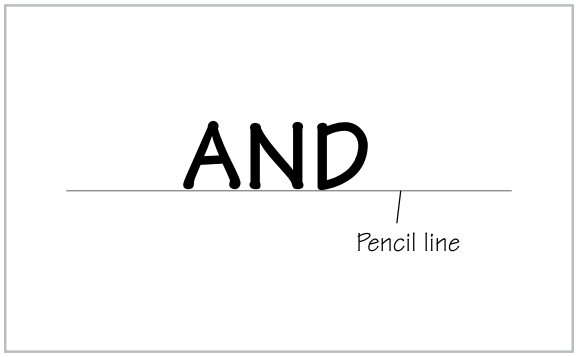


Illustration 2.3—Applying Lettering

- Unless you are an expert calligrapher, always use a lettering set to write text, or use transfer type for applying lettering to drawings. If you use a lettering set, use a pencil line for aligning the letters, as shown in Illustration 2.3. Do not use a pencil line for aligning transfer type, because the line cannot be erased later without also rubbing off the letters. Misplaced transfer type may be lifted off with tape, but be careful not to damage the paper. Be careful not to rub off the letters after they are applied.
- Do everything with great care and patience.

Practice, Practice, Practice

If you are unfamiliar with doing high-quality ink drawings, you should not make your drawing project your first ink-drawing experience. If you do, you will make mistakes right from the start, get discouraged, and give up. Instead, you should practice drawing basic shapes—such as straight lines, rectangles, circles, and corners—with the techniques presented above, so that you become familiar with the tools and medium (ink and paper). Reading one of the books recommended at the beginning of the chapter will be helpful. Next, you should practice drawing more complex shapes, such as the more difficult portions of the drawing you ultimately want to do. By becoming familiar with the tools and techniques first, you will avoid becoming discouraged before you start your project.

Tracing Photographs and Objects

You can produce accurate drawings with relative ease by either tracing photographs of an object, or by tracing the actual object.

Tracing Photographs

To trace a photograph or other printed graphics, follow these steps:

1. Take close-ups of the object. It should appear as large as possible in the photos. Make 4" × 6" or larger prints, so that the image of the object is large enough to produce the right

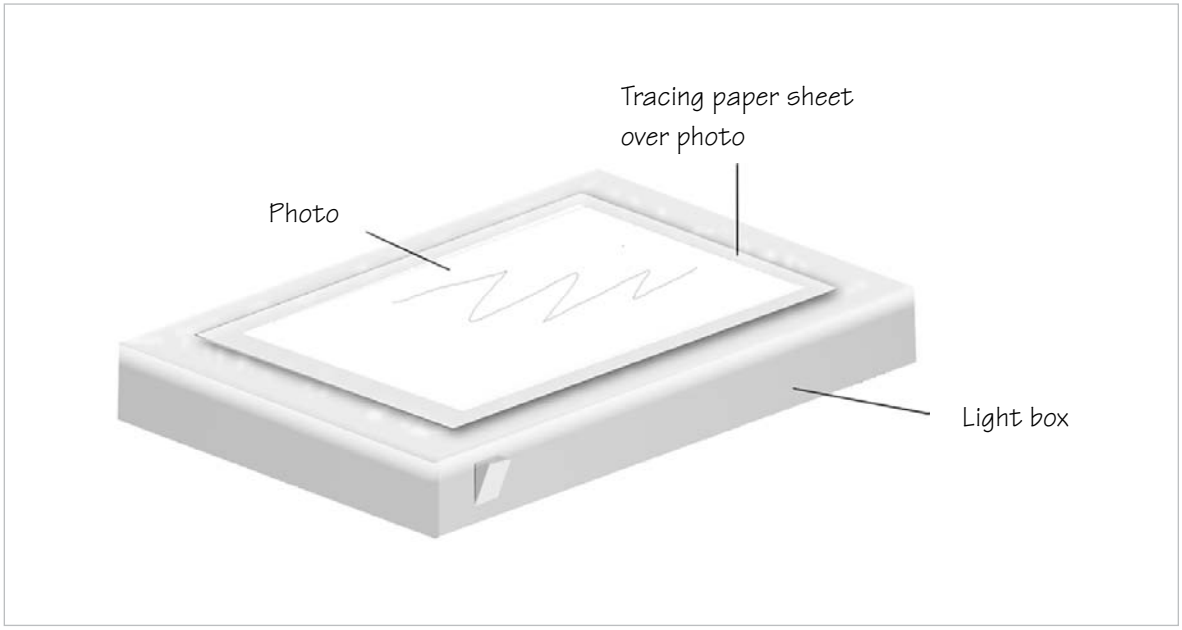


Illustration 2.4—Tracing a Photo

sized drawing. See Chapter 4 for details on how to take suitable photographs.

2. Tape the photograph on a light box and tape a piece of vellum over it, as shown in Illustration 2.4.
3. Trace the photograph very carefully and lightly with a pencil. Avoid making dark lines or pressing too hard and scribing grooves in the paper.
4. Mount the paper on a drafting board, ink over the pencil lines, and erase the pencil marks. Always draw ink lines with the aid of rulers and templates. When inking circles, ovals, or curves, select a template that most closely matches the shape desired.
5. After the ink is completely dry, erase any pencil marks that remain visible outside the ink lines.

Tracing an Object With a Camera Lucida

To trace an actual object with a camera lucida, follow these steps:

1. Mount the arm on a table, and position the lens over a sheet of paper, as shown in Illustration 2.5.
2. Position the object on the table.
3. Look through the lens at the paper with one eye, and adjust the positioning of the lens and the object until an image of the object appears on the paper.
4. Adjust the distance of the object, or change the lens to adjust the image size on the paper.
5. Trace the image lightly with a pencil. You may trace freehand or with the aid of rulers and templates. Keep your head steady to

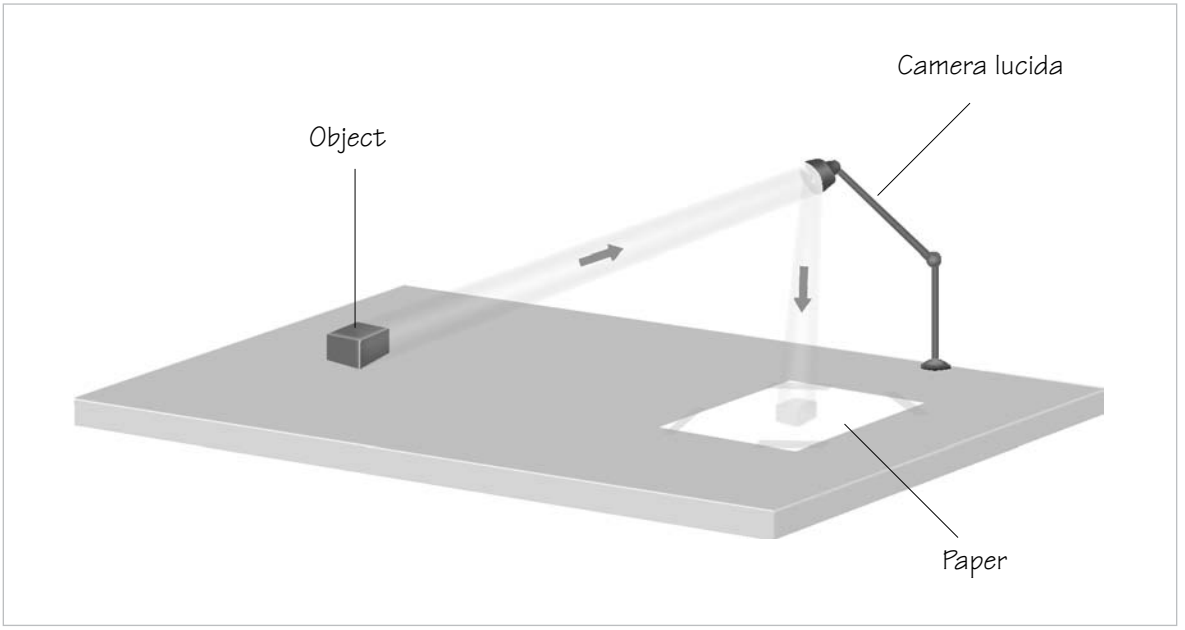
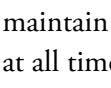


Illustration 2.5—Using a Camera Lucida

maintain the image's position on the paper at all times. Every time you move your head away from the lens and go back later, you must realign the image with the lines on the paper.

6. After you finish tracing, mount the paper on a drafting board and ink over the pencil lines. Always draw ink lines with the aid of rulers and templates. When inking circles, ovals, or curves, select templates that most closely match the shapes desired, or use an adjustable curve. If you trace freehand, the pencil lines will be somewhat crooked, so you should apply the ink lines for a best fit.
7. After the ink is completely dry, erase any stray pencil marks that remain visible outside the ink lines.



TIP

Tracing with the camera lucida is relatively difficult, because you must keep your head very still while your hand moves. Tracing a photograph is much easier.

Tracing an Actual Object With a Direct-View Device

To trace an actual object with a direct-view device, as discussed above, follow these steps:

1. Position the object on the ground, and orient it for a suitable view (front, side, top, and so on.) when seen from above. Use tape, blocks, modeling clay, earthquake wax, or whatever is suitable to fix it in the desired position, as shown in Illustration 2.6.

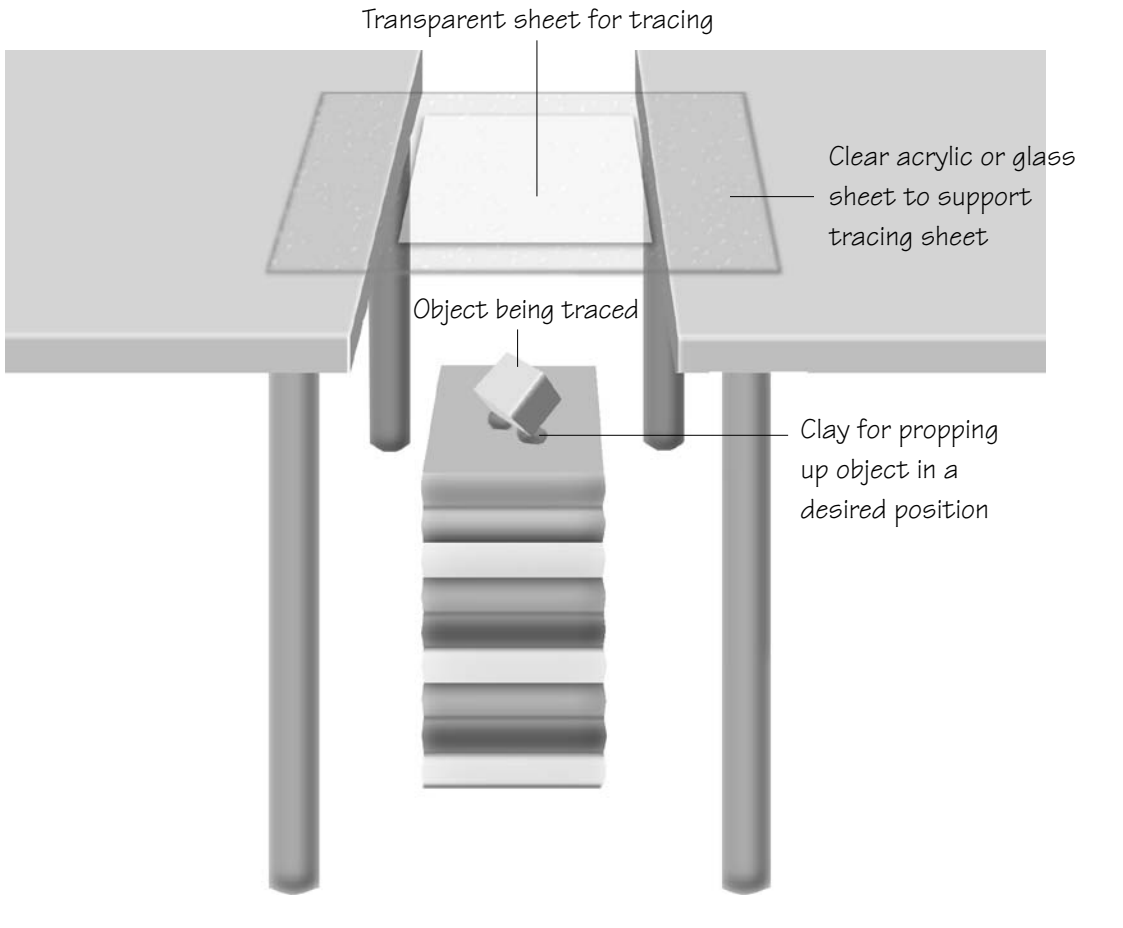


Illustration 2.6—Tracing an Actual Object

2. Tape a sheet of polyester film on a sheet of transparent acrylic.
3. Position the acrylic sheet over the object and adjust the height or distance of the sheet so that the object fits within the desired drawing area of the polyester film. There is no commercially available device for supporting the acrylic sheet for this purpose, so you will have to use your ingenuity to devise a solution. One possibility is to support the acrylic sheet between two tables of identical height (or in the gap made when the leaf is removed from a pull-apart table), and position the model below the acrylic sheet (Illustration 2.6). The object can be lifted off the ground with a stack of magazines or encyclopedias to adjust its distance from the acrylic sheet. Another possibility is to support the sheet between the heads of two camera tripods, which can be easily adjusted to support the sheet at a range of different heights. For a larger object that requires a greater distance to fit within the tracing film, the acrylic sheet may be positioned vertically and spaced horizontally from the model. This may be done on a long table, as shown in Illustration 2.7, or with tripods, as shown in Illustration 2.8.
4. Close one eye. Position yourself so that you see the object within the desired part of the polyester film. Select two opposite corners of the object and mark them. Whenever you are tracing, you must keep the same

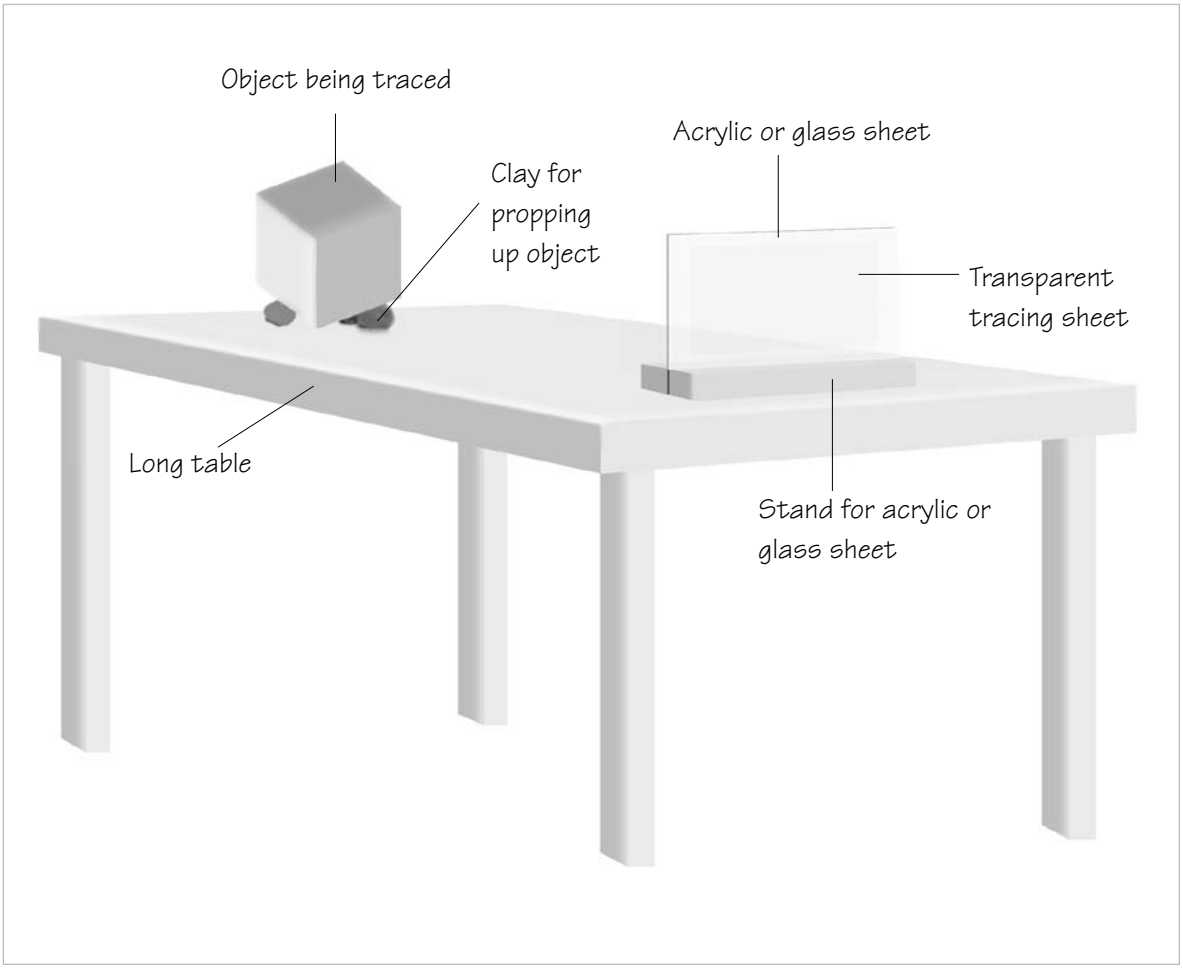


Illustration 2.7—Tracing a Large Object on a Long Table

eye closed and see with the other eye, or parallax will cause substantial errors in the drawing.

5. Trace the model very carefully with a pencil. You must hold your head steady to keep the object lined up with the marks when you are tracing. Whenever you move away from—and later come back to—the model, you must adjust your head's distance and lateral position to line up the object with the marks again.
6. After tracing is completed on the polyester film, tape it on a light box, tape a sheet of vellum over it, as shown in Illustration 2.4, and lightly trace the drawing onto the vellum with a pencil. Be careful not to press too hard and scribe grooves into the paper.
7. Mount the vellum on a drafting board, and ink over the pencil lines. Always draw ink lines with the aid of rulers or templates. When inking circles, ovals, or curves, select templates that most closely match the shapes desired. If you trace freehand, the pencil lines will be somewhat crooked, so you should apply the ink lines for a best fit.
8. After the ink is completely dry, erase any pencil marks that remain visible outside the ink lines.

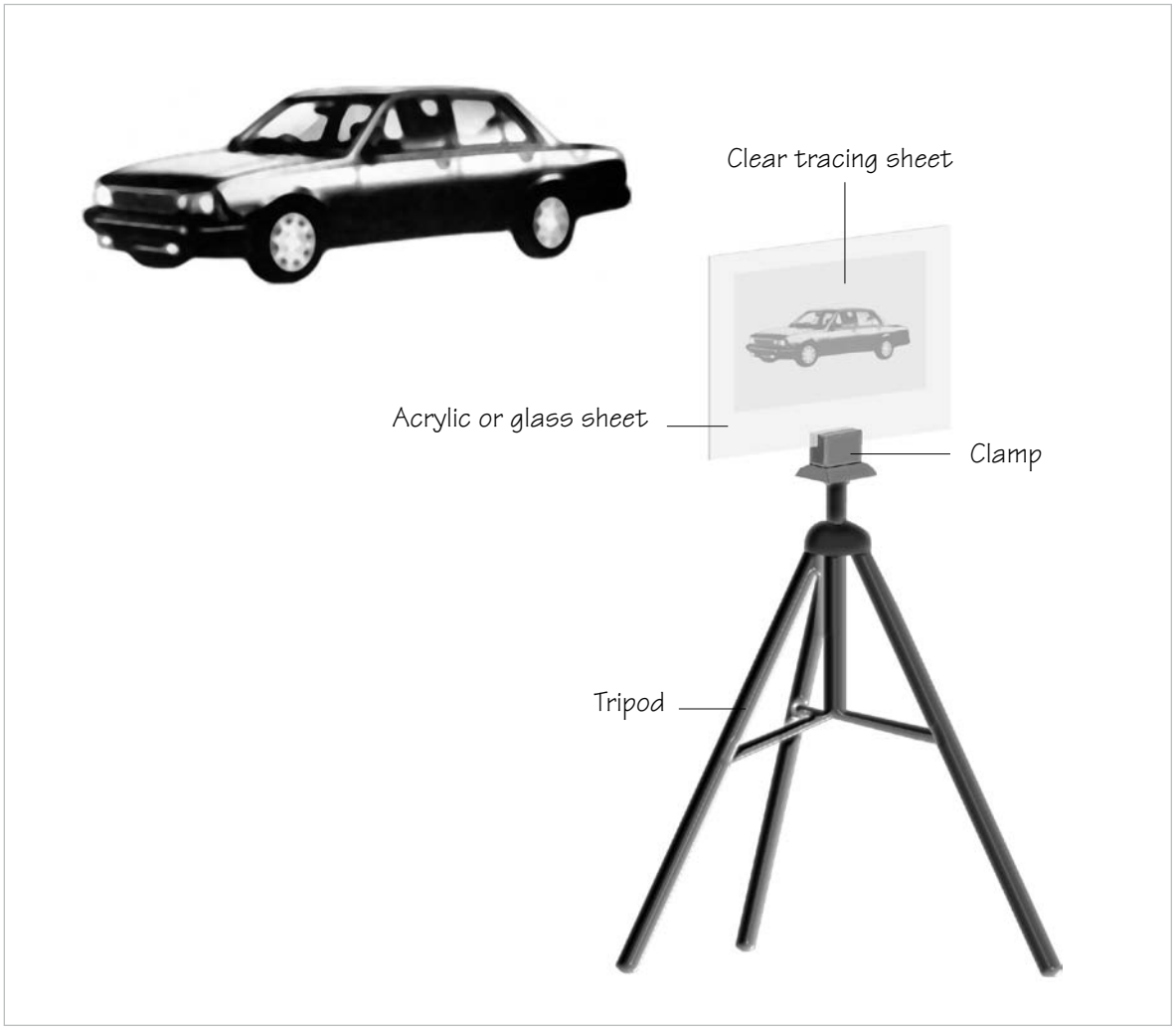


Illustration 2.8—Tracing a Very Large Object

TIP

Although it is a very inexpensive technique, tracing with the direct-view device is about as difficult as using the camera lucida, because you must also keep your head very still while your hand moves. Tracing a photograph is much easier, but relatively more expensive.

Enlarging or Reducing a Tracing

In patent drawings, each figure should be large enough to show essential details clearly without crowding, but should not be unnecessarily large. If your tracing is not of a suitable size, you may resize it with the following method:

1. Enlarge or reduce the tracing with a photocopier. You can enlarge an enlargement or reduce a reduction to make even bigger or smaller copies, respectively.
2. Mount the photocopy on a light box and mount another sheet of paper over it.
3. Trace the photocopy lightly in pencil.
4. Mount the second tracing on a drafting board and ink over the lines. Always draw ink lines with the aid of rulers or templates. When inking circles, ovals, or curves, select templates that most closely match the shapes desired. If you trace freehand, the pencil lines will be somewhat crooked, so you should apply the ink lines for a best fit.
5. After the ink is completely dry, erase any stray pencil marks that remain visible outside the ink lines.

Drawing From Your Imagination

If the object you wish to draw does not exist, you cannot base the drawing on its actual shape as you can when tracing and will have to base the drawing solely on a mental image.

Sketching the Figures

To create a drawing from your imagination, sketch the figures as follows:

1. Use a sheet of vellum, and start by lightly sketching a rough shape of the object you have in mind, as shown in Illustrations 2.9 and 2.10. For long objects, such as airplanes, human limbs, or table legs, start by drawing centerlines, then add the outline around the centerlines. Don't worry about the details. Concentrate on getting the proportions and perspective right. If you fuss with the details, you will lose sight of the overall proportion and shape of the object and come up with something distorted. The pencil marks must be light enough so that they can be completely erased later.
2. Sketch the major features of the object to refine the drawing a little more.
3. Fine-tune the lines and add small details.

This technique is akin to seeing an image through a pair of binoculars that are initially out of focus for you. At first, you can see only a rough shape, but as you adjust the focus, the image slowly becomes sharper to reveal more of its shape, until the focus is perfectly adjusted and you can see all the details clearly.

Study Similar Objects for Clues

If you have trouble making a drawing look right, study an object—or a drawing or photo of an object—that is shaped similarly to the one you wish to draw, or the portion of the object you are drawing. For example, if you have trouble drawing a box in perspective, find a similar box, position it in the same view angle that you are drawing, and study its lines to get an idea of what they should look like, as shown in Illustration 2.11. Photos and drawings of many objects can be found in a visual dictionary

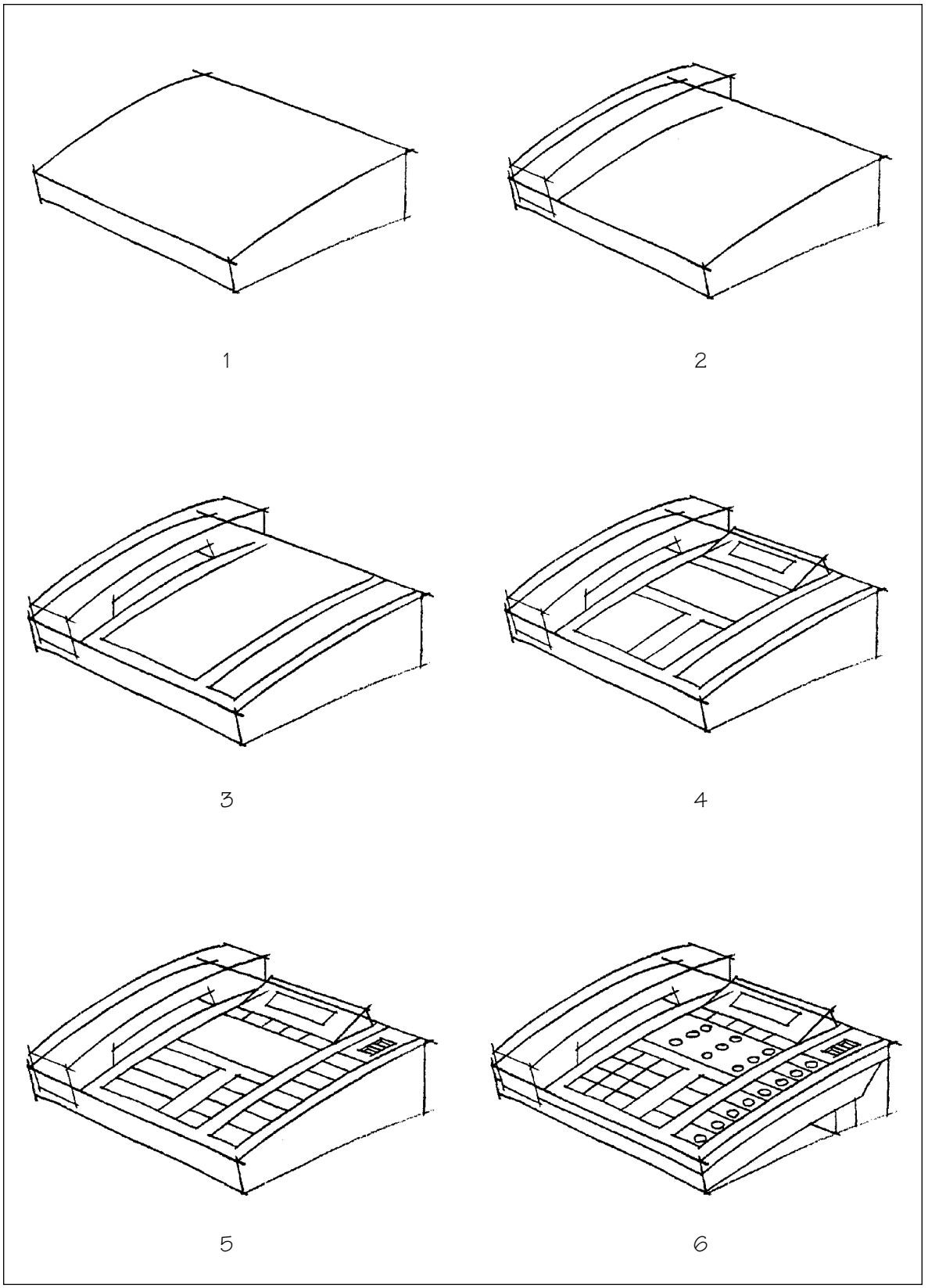


Illustration 2.9—Sketching Technique

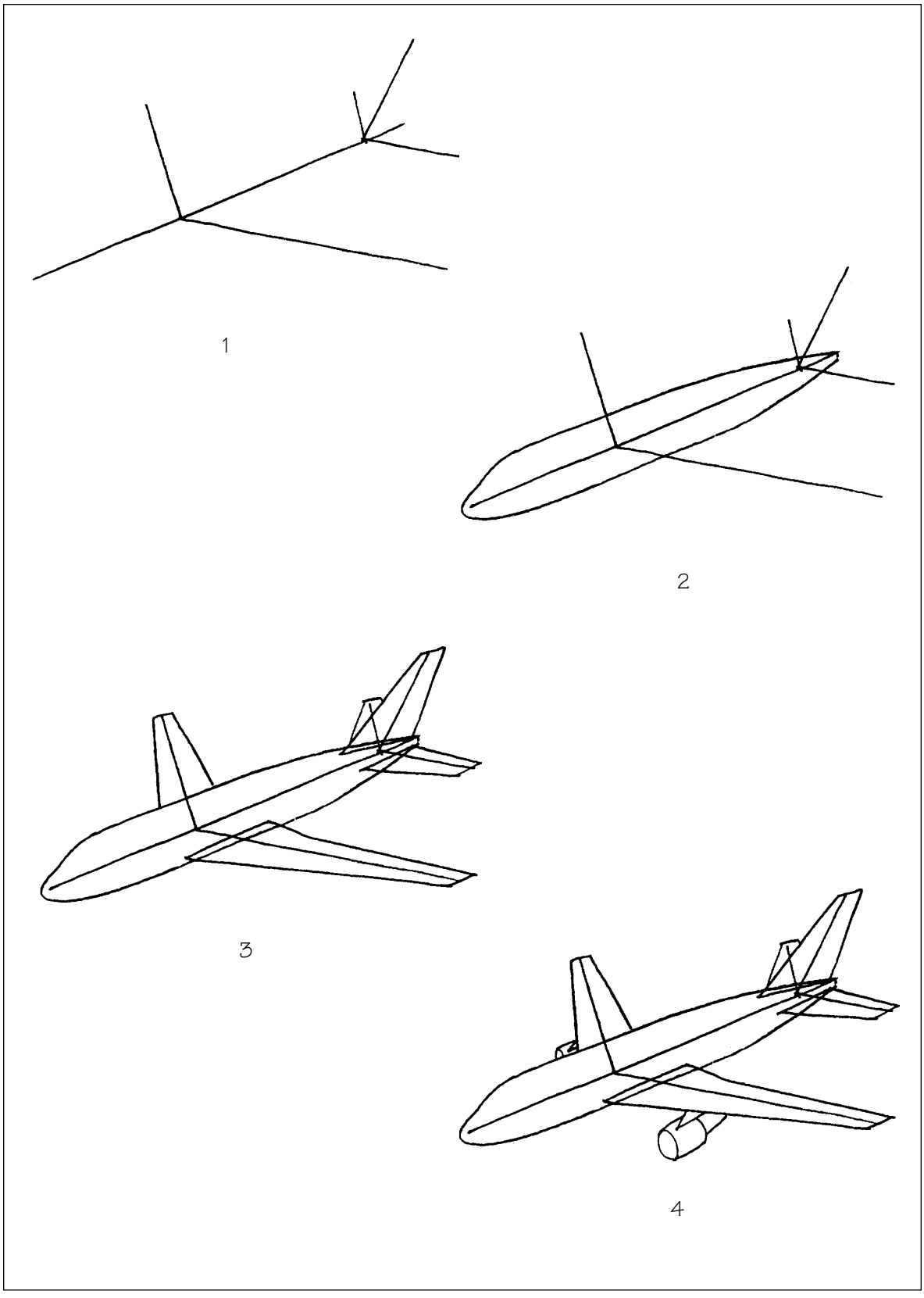


Illustration 2.10—Sketching Technique

such as *The Firefly Visual Dictionary* by Corbeil and Archambault (Firefly).

When studying the lines, look for qualities such as their angles relative to the vertical or horizontal, angles relative to other lines on the same object, and the relative length of each line with respect to other lines on the same object. If you are careful in making these observations, you should be able to create satisfactory drawings. However, if you are still having a great deal of difficulty, you may consider making a model and tracing it, as described above, or using a computer. (See Chapter 3 on drawing with a computer.)

Since patent drawings are not art, but technical illustrations, your drawings do not have to be artistically perfect or beautiful. However, they do have to be reasonably accurate and communicative in depicting the structure of the invention.

Page Layout

Each figure (drawing) should be big enough to show all of its details clearly. If several different figures are still small enough, they should be placed on the same sheet of paper to avoid using too many sheets. If you know the drawings will fit on the same sheet, but you have difficulty positioning them during the sketching process, you can draw them on different sheets, cut them out, paste them on one sheet, and then make a photocopy. If the figures are too large to fit on one sheet, just use as many additional sheets as necessary.

Ink in the Lines

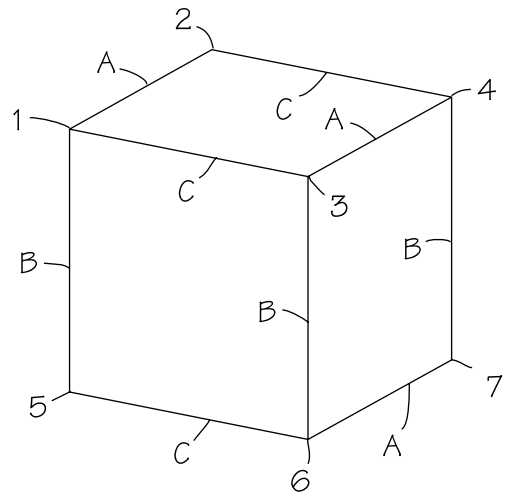
After the sketch is complete, trace over the pencil lines with ink. You should always use rulers and templates to guide the ink pen, and avoid drawing anything freehand as much as possible. When you are sure the ink is completely dry (the ink is still wet if it is shiny), carefully erase any stray pencil marks that remain visible outside the ink lines. If you are impatient and start erasing too soon, the eraser will smear the wet ink lines.

Trace Over the Sketch If Necessary

A sketch is sometimes so rough that its lines are each formed by a jumble of pencil marks, so that the exact placement of the final ink line is unclear, as shown in Illustration 2.12. Instead of risking a permanent mistake by inking over a rough sketch, you can put a fresh piece of paper on it, and trace the sketch carefully with a pencil on a light box. The tracing should be much clearer, so that you can apply ink lines on it with confidence.

Drawing to Scale

Although the PTO does not require that drawings be scaled proportionately, it is best to do so. Doing the drawings is much easier if you have some idea about the dimensions of the object you wish to draw, because such dimensions will enable you to draw the object with the correct proportions. If you have the object available, you can use a ruler to measure all of the critical dimensions and a protractor to measure the angles of angled lines and surfaces. But then again, if the object is available, tracing it is easier. If you don't have the object, you can create some estimated measurements.



Note that:
Lines A are about 30 degrees above horizontal and parallel to each other.

Lines B are vertical and parallel to each other.

Lines C are about 10 degrees below horizontal and parallel to each other.

Point 1 is positioned about midway between Points 3 and 4 along the vertical direction.

Point 2 is positioned about midway between Points 1 and 3 along the horizontal direction.

Point 4 is positioned about midway between Points 1 and 2 along the vertical direction.

Point 6 is positioned about midway between Points 2 and 4 along the horizontal direction.

Illustration 2.11—Studying Objects for Clues

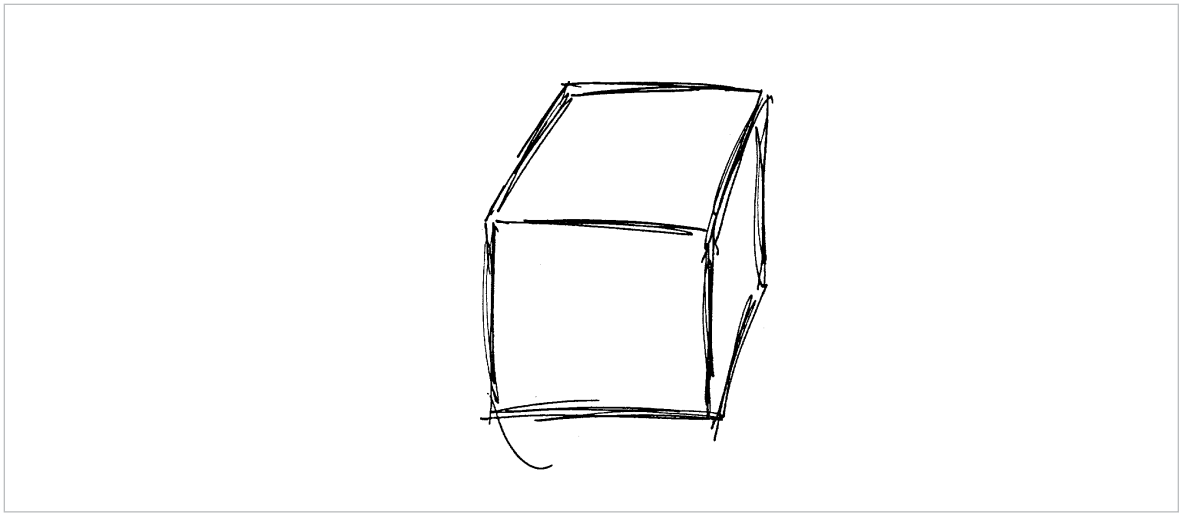


Illustration 2.12—Rough Sketch Makes Final Line Placement Unclear

Use Metric Measurements If Possible

If you can immediately tell whether 2 5⁄16" or 2 11⁄32" is longer, you are very familiar with the U.S./English measurement system (inches, feet, and so on). Otherwise, you should use metric units, such as millimeters (mm), centimeters (cm), and meters (m), which are based on multiples of ten. For example, 10 mm equals 1 cm, 100 cm equals 1 m.

With the metric system, it is immediately apparent to anyone that, for example, 6.24 cm is longer than 6.22 cm. Also, the millimeter, which is about the thickness of a dime, is a fine enough measurement for most tasks. The centimeter is equal to 0.39 inch, which is roughly equal to the diameter of a typical pen. As long as you remember visually how long the millimeter and the centimeter are, adapting yourself to work with the metric system is easy.

Converting Dimensions With a Scale Rule

Drawing to scale is easy with a scale rule. For example, if an object is 46 cm (18.1") tall and 20 cm (7.9") wide, you can use a 1:2 scale rule to draw it at half its actual size, so that it is about 23 cm (9") tall and 10 cm (4") wide to fit on a sheet of letter-size paper.

Converting Dimensions Manually

If there is no suitable scale rule for an object —that is, if you need to reduce or enlarge it at some odd scale—you can convert the dimensions manually. For example, if an object is 30 cm (11.8") tall, and you want to scale it down to about 23 cm (9") tall to fit on a sheet of letter-size paper, you would divide 23 by 30 to get a reduction ratio of 0.77, then multiply all other actual dimensions by 0.77 to get the scaled-down dimensions of the drawing. Conversely, if an object is only 3.4 cm (1.3") tall, you can enlarge it to make a clearer drawing. You can scale it up to, say, 20 cm (7.9") tall by dividing 20 by 3.4 to get

an enlargement ratio of 5.88, then multiply all other actual dimensions by 5.88 to obtain the drawing dimensions.

Use the following steps to scale dimensions manually:

1. Determine the maximum height and width of the object to be drawn—for example, 20 cm tall and 30 cm wide.
2. Determine the maximum height and width of the desired drawing area—for example, 23 cm tall and 18 cm wide.
3. Determine the scaling factor. In this example, although the object is not as tall as the drawing area, it is wider than the width of the drawing area, so it has to be reduced to fit. Therefore, divide the width of the drawing area (18 cm) by the width of the object (30 cm) to obtain 0.60, which is the scaling factor.
4. Multiply all the actual dimensions of the object by the scaling factor to obtain the scaled dimensions. In this example, multiply all the actual dimensions of the object by 0.60 to obtain the scaled dimensions. For example, multiply 20 cm (height of object) by 0.60 to obtain 12 cm as the height of the drawing, multiply 30 cm (width of object) by 0.60 to obtain 18 cm as the width of the drawing, and multiply all other dimensions accordingly.

Actual or Reduced Scale

If the object is just the right size to fit on a sheet of paper, it may be drawn at actual size—that is, a scale of 1:1. If your drawing is to a different scale after you have scaled all the important dimensions, draw the object by drawing each line with the scaled dimension, as shown in Illustration 2.13, which illustrates a vacuum sander.

Drawing Different View Angles

You may choose to illustrate an object with only orthogonal views (front, side, top, and so on), because these are relatively easy to do. However, if they do not illustrate the object clearly enough, you should also draw one or more perspective views, which may be drawn with foreshortening if desired.

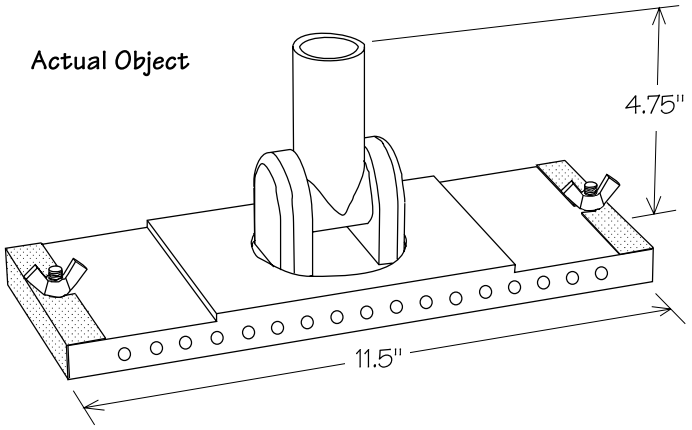
Orthogonal Views

In an orthogonal view, the object is drawn as if one side of it is parallel to the drawing surface. A tapered block is used to illustrate the point in Illustration 2.14. Imagine positioning a sheet of paper parallel to the front side of the block, and projecting an image of the block onto the paper. Any surface that is parallel to the paper appears at full size. For example, the size of the front side's image is the same as that of the actual block's—that is, height "B" of the image is the same as height "B" of the actual block. Orthogonal views typically include many vertical or horizontal lines that represent the sides, top, and bottom of an object.

Angled Lines in Orthogonal Views

Surfaces that are angled relative to the drawing sheet do not appear at full size: The more angled the surface is to the drawing sheet, the smaller its image appears. For example, the slanted surface of the block in Illustration 2.14 is at a large angle relative to the drawing sheet. It is quite long on the actual block, but its image on the drawing sheet appears much shorter: The size "A" of the slanted surface on the drawing sheet is the same as height "A" on the actual block.

Surfaces that are at a right angle to the drawing sheet appear to have zero height—that



Simple calculations converting dimensions:

Actual Dimensions	x Scale Factor	= Drawing Dimensions
11.5"	0.6	6.9"
4.75"	0.6	2.85"

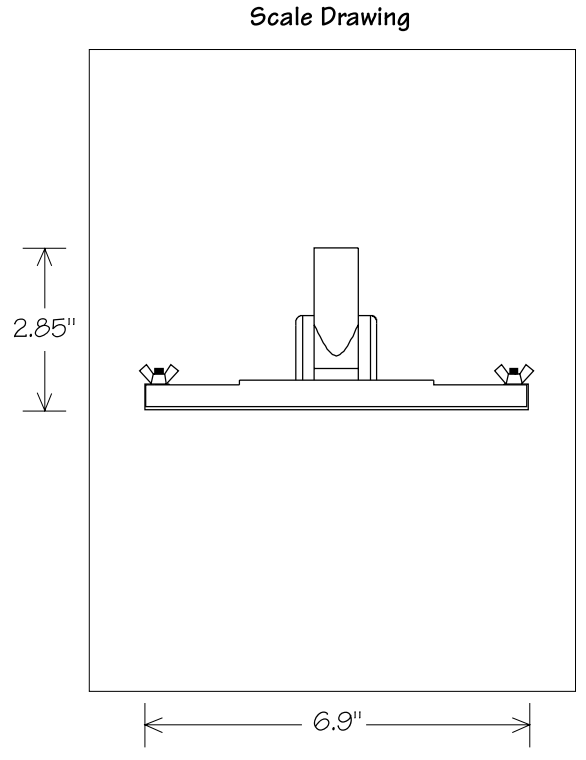


Illustration 2.13—Scale Drawing

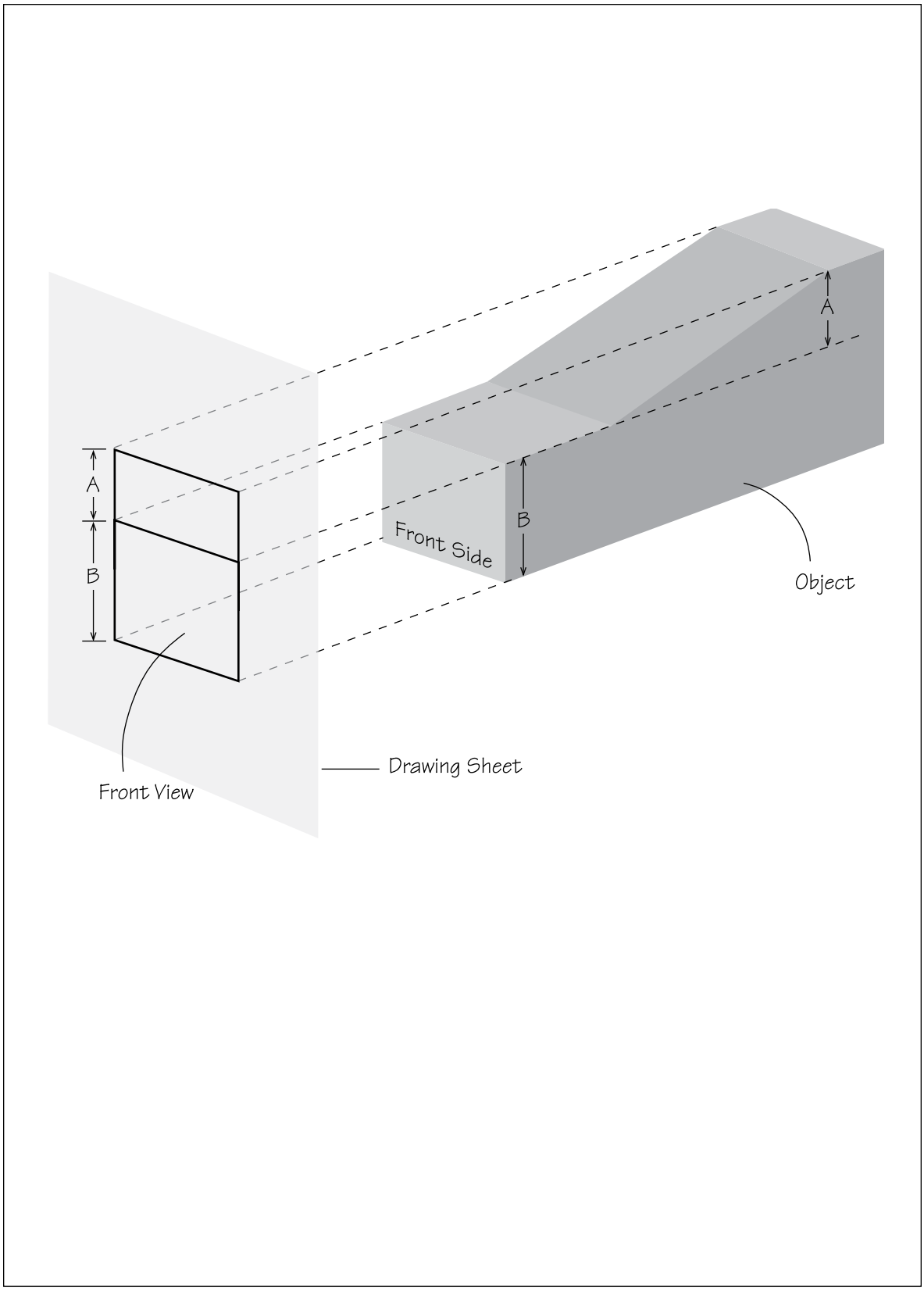


Illustration 2.14—Angled Lines in Orthogonal View

is, they appear as single lines. For example, the bottom surface of the block is precisely at a right angle to the drawing sheet, so that it appears as a single horizontal line on the drawing sheet. The same goes for the sides and top of the block.

Perspective Views

Illustration 2.15 shows a box and a cylinder as viewed from different angles to illustrate what objects in perspective look like. Note that the views taken from the same height as the objects are not as clear as those that are taken above or below. Also note that the sides of the objects appear at full height when seen at the same level, but they appear shorter when the objects are seen from slightly below or slightly above—and even shorter when the objects are seen from almost directly below or almost directly above. The inverse is true for the tops and bottoms, which are not visible (having a zero height) when seen at the same level, but they appear larger when the objects are seen from slightly below or slightly above, and even larger when the objects are seen from almost directly below or almost directly above.

It is not possible to show in this book what every possible shape would look like from different angles. Illustration 2.15 serves as a rough guide to help you imagine how your drawing should look. If you still have trouble, study similar objects for clues.

Circles in Perspective

Circles appear as ellipses (squashed circles) in perspective views. An ellipse has a major axis (the line extending across the widest part of the ellipse) and a minor axis (the line extending across the narrowest part of it). The drawing of a cylindrical rod and a hole on a box are shown in Illustration 2.16. The dashed lines are all temporary lines that should be sketched lightly in pencil and erased later.

Drawing a Cylindrical Rod

1. Draw the parallel sides of the cylinder.
2. Sketch the major axis of the ellipse between the ends of the sides. The major axis is the same as the diameter of the cylinder.
3. Sketch the minor axis perpendicular to and through the midpoint of the major axis. The more perpendicular the cylinder is to the drawing surface (the more the end of the cylinder is seen straight on), the longer the minor axis; whereas the more oblique (angled) the cylinder is to the drawing surface (the more the end of the cylinder is angled away), the shorter the minor axis. The length of the minor axis is difficult to determine exactly, so simply use a length that makes the ellipse look "about right."
4. Draw the ellipse so that it is symmetrical about the major axis and symmetrical about the minor axis.

Drawing a Hole on a Box

1. Determine the center of the hole and draw the centerline, which is perpendicular to the front side of the box, and parallel to the horizontal edges of the box.
2. Sketch the major axis of the ellipse through the center and perpendicular to the centerline. The midpoint of the major axis should coincide with the center of the hole.
3. Sketch the minor axis perpendicular to and through the midpoint of the major axis. The more perpendicular the hole is to the drawing surface (the more the hole is seen straight on), the longer the minor axis; and the more oblique the hole is to the drawing surface (the more the hole is seen angled away), the shorter the minor axis. Again, the length of the minor axis is difficult to determine exactly, so simply use a length that makes the ellipse look "about right."

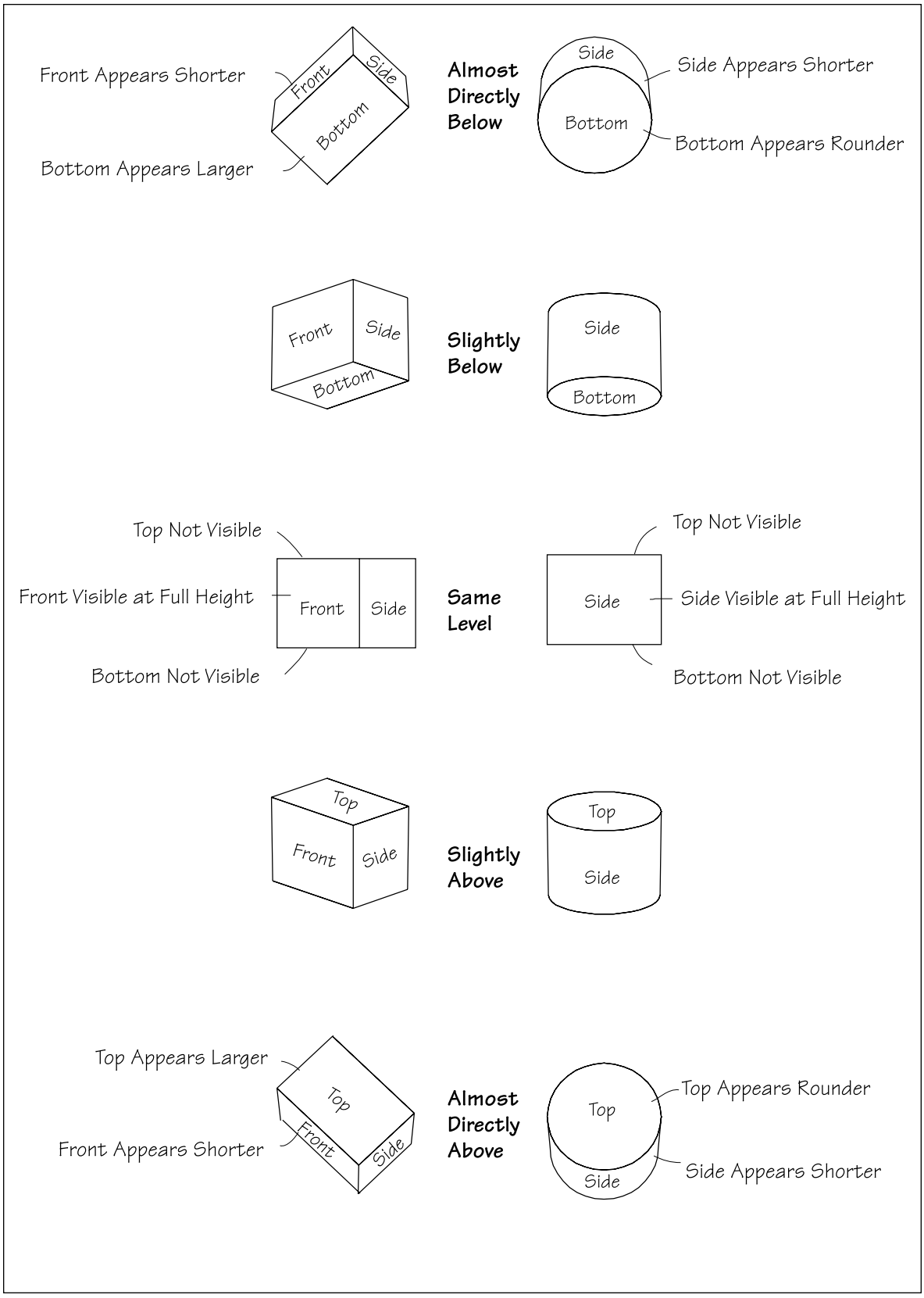


Illustration 2.15—Perspective Views

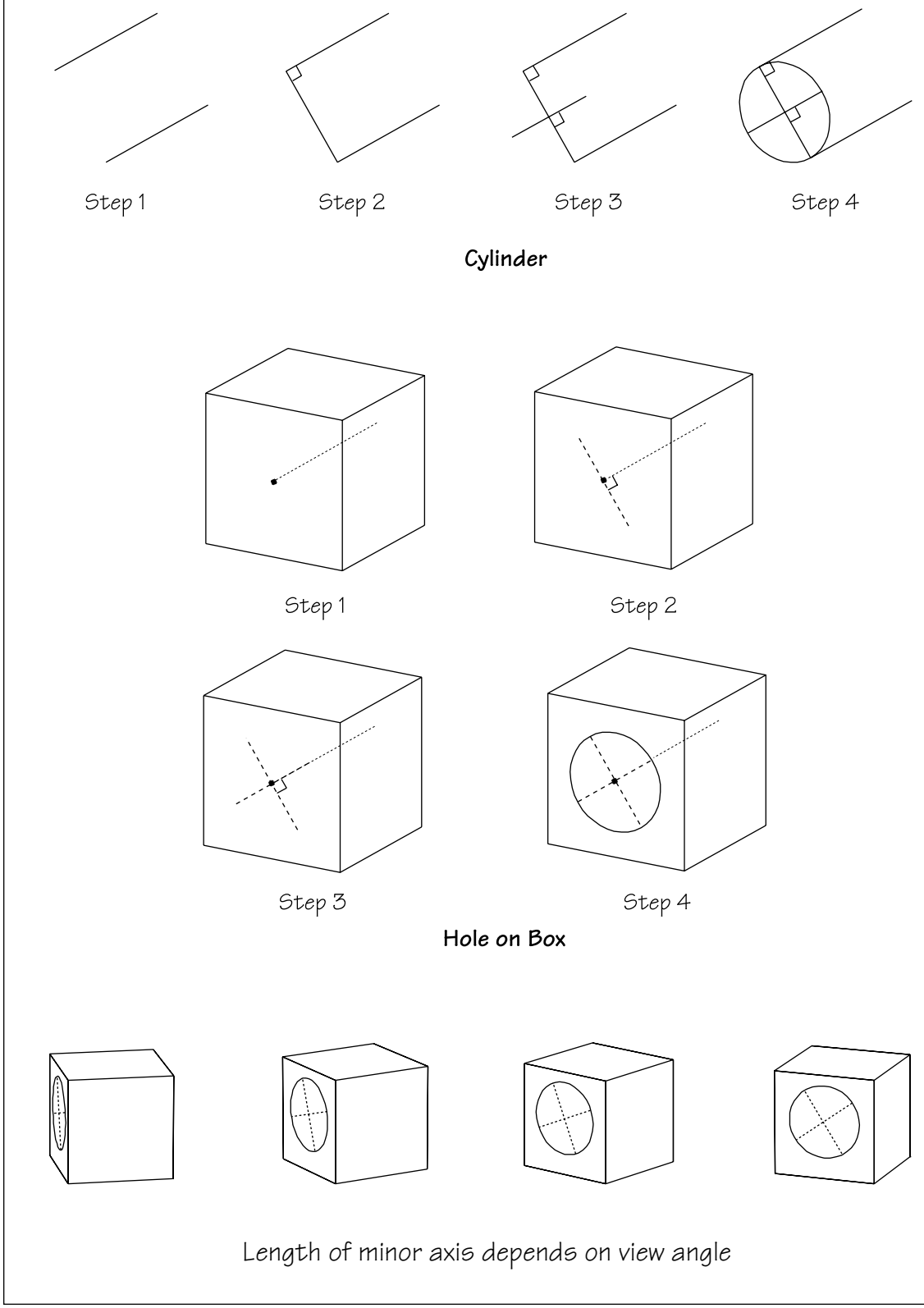


Illustration 2.16—Circles in Perspective

4. Draw the ellipse so that it is symmetrical about the major axis, and symmetrical about the minor axis.

Sketching an accurate ellipse is difficult to do freehand, so you should use an ellipse template that most closely matches the desired shape. If you have an ellipsograph, you can draw a more precise ellipse.

Translating Views by Plotting

A method for translating an orthogonal view into a perspective view comprises covering the orthogonal view with a grid, then plotting and connecting points on another grid drawn in perspective, as shown in Illustration 2.17. The finer the grid, the higher the plotting accuracy. The grid may be applied on the orthogonal view in pencil or by covering it with a transparent grid overlay. The grid for the perspective view may be lightly drawn in pencil, so that it may be erased later.

Approximated Perspective Views

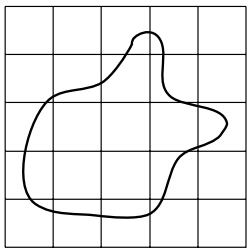
A perspective view may be easily approximated by basing it on an orthogonal view, as shown in Illustration 2.18. The perspective view is done by simply drawing oblique (slanted) lines from the orthogonal view, which may be a front, back, top, bottom, or side view. This is akin to making an extrusion of the object, like squeezing toothpaste out of a tube. The oblique lines should be relatively short—much shorter than their actual dimensions—otherwise the perspective view will appear distorted. Such approximated views are not truly perspective, but they are usually acceptable for patent drawings.

Drawing Graphical Symbols

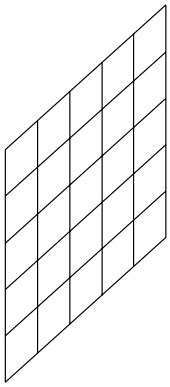
Graphical symbols, such as flowcharts and electrical schematics, are relatively easy to draw. There are many other types of graphical symbols used in patent drawings, including fluid-power, architectural, chemical, genetic, and so on. It is beyond the scope of this book to discuss the meaning and use of such symbols. If you are unfamiliar with them, you must refer to the literature in the relevant field for guidance.

When drawing graphical symbols, the only problem is arranging the elements of the drawing so that they fit onto a sheet. Use the following method:

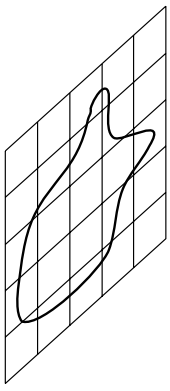
1. Sketch the drawing roughly in pencil first to get an idea of its layout on the sheet.
2. If the position of the drawing needs adjusting, you can trace it onto another sheet in the desired position.
3. If the sketch grows too large to fit onto a single sheet, make another sketch by packing the elements closer together. If that is not possible, or if it makes the elements too crowded, the drawing may be spread over multiple sheets. See Chapter 6 for instructions on making multiple-page drawings.
4. When you have a satisfactory rough sketch, carefully sketch in the details, using suitable guides to ensure that they are aligned properly. There are templates available for a variety of different symbols, so use them whenever possible. They will make drawing much faster and more accurate.
5. Ink in the lines, and erase any stray pencil marks that remain visible after the ink is completely dry.



Step 1: Position grid on object.



Step 2: Sketch grid in perspective.



Step 3: Plot object on grid.

Illustration 2.17—Translating Orthogonal View Into Perspective View by Plotting

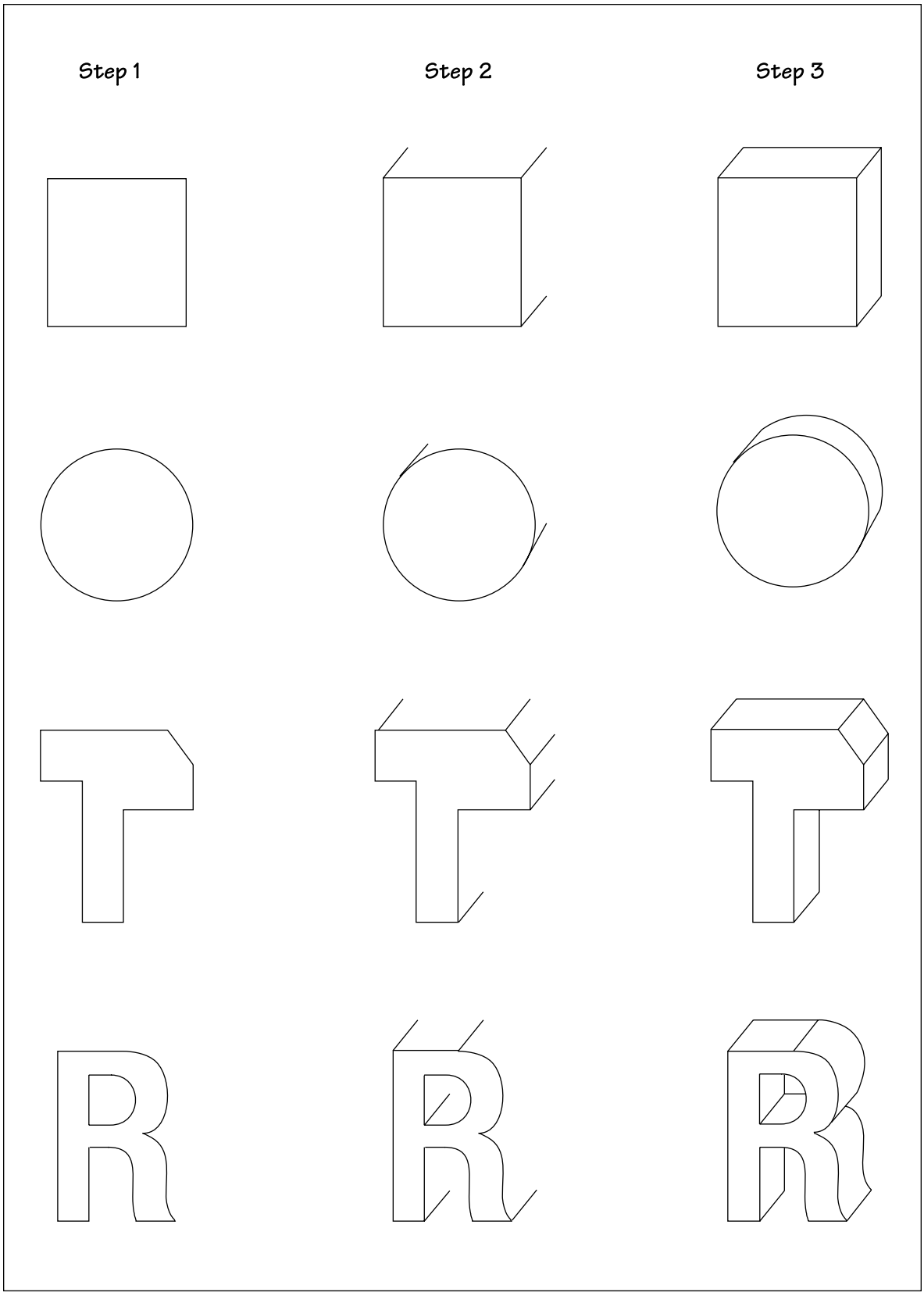


Illustration 2.18—Approximated Perspective View

Practice, Practice, Practice

Remember that if you have never done high-quality drawings before, you should learn and practice basic drawing techniques before starting on your patent drawing project. If you follow this simple and obvious bit of advice, you will ultimately achieve much better results. Again, refer to the books listed at the beginning of this chapter for basic drawing techniques.